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TACTICAL COMMUNICATIONS ANALYSIS PROGRAM USER'S MANUAL

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The Tactical Communications Analysis Program (TACP) User's Manual describes the applicability of, data required for, and operational instructions for the TCAP. The TCAP was developed for the U.S. Marine Corps to perform electromagnetic compatibility analyses of snapshot deployments of tactical communications equipments operating in the HF (2-30 MHz), VHF (30-76 MHz), and UHF (225-400 MHz) frequency bands. This manual supersedes ESD-TR-74-070.

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PREFACE

The Electromagnetic Compatibility Analysis Center (ECAC) is a Department of Defense facility, established to provide advice and assistance on electromagnetic compatibility matters to the Secretary of Defense, the Joint Chiefs of Staff, the military departments and other DoD components. The center, located at North Severn, Annapolis, Maryland 21402, is under executive control of the Office of the Secretary of Defense, Director of Telecommunications and Command and Control Systems and the Chairman, Joint Chiefs of Staff, or their designees, who jointly provide policy guidance, assign projects, and establish priorities. ECAC functions under the direction of the Secretary of the Air Force and the management and technical direction of the Center are provided by military and civil service personnel. The technical operations function is provided through an Air Force sponsored contract with the IIT Research Institute (IITRI).

This report was prepared as part of AF Project 649E under Contract F-19628-76-C-0017 by the staff of the IIT Research Institute at the Department of Defense Electromagnetic Compatibility Analysis Center.

To the extent possible, all abbreviations and symbols used in this report are taken from American Standard Y10.19 (1967) "Units Used in Electrical Science and Electrical Engineering" issued by the United States of America Standards Institute.

Users of this report are invited to submit comments which would be useful in revising or adding to this material to the Director, ECAC, North Severn, Annapolis, Maryland 21402, Attention ACW.

EXECUTIVE SUMMARY

The United States Marine Corps tasked the Electromagnetic Compatibility Analysis Center (ECAC) to perform an electromagnetic compatibility (EMC) analysis of typical deployments of both present and future tactical communications systems through 1985 as projected by the Landing Force Integrated Communications System (LFICS).

A computer program entitled the Tactical Communications Analysis Program (TCAP) was developed to perform the required EMC analysis for equipments operating in the HF (2-30 MHz), the VHF (30-76 MHz), and the UHF (225-400 MHz) frequency bands. Only the groundwave mode of propagation is considered for the HF (2-30 MHz) band.

This report, a users guide for TCAP, updates and supersedes ESD-TR-74-70. The guide is designed as an aid in determining the applicability of TCAP to user problems and to identify data that must be supplied as inputs to the TCAP. The guide also furnishes procedural information necessary to run TCAP at the ECAC computer facility.

The information presented herein covers the general objectives of TCAP along with its capabilities, assumptions, limitations, and options. The input data required and the outputs produced are described in general terms. For personnel associated with the execution of the program, a detailed description of the inputs, and associated formats is presented and discussed. A sample computer runstream, including control cards, is provided and sample outputs are shown.

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SECTION 1

INTRODUCTION

BACKGROUND

The Tactical Communications Analysis Program (TCAP) was developed by ECAC for the U. S. Marine Corps as part of the study of the Landing Force Integrated Communications System (LFICS)[1] TCAP was designed as an analytical procedure for use in examining the performance of communications equipment of a tactical deployment at specific moments in time (Snapshots). TCAP is used to determine if all desired communications meet a minimum acceptable communications quality and then to determine the minimum frequency separations required between all nets in order to maintain that communications quality. The program has general applicability to present deployments or conceptual deployments consisting of future communications systems for which equipment characteristics and parameters can be estimated. The program is currently applicable to ground-to-ground, air-to-ground, and tactical satellite communications in the VHF (30-76 MHz)[2] and UHF (225-400 MHz)[3,4] frequency bands of operation and to the groundwave mode of operation in the HF (2-30 MHz) band.

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[1]Enclosure (4) to CMC ltr. AX/A04C-jlc-611, dtd. 13 October 1971.

[2]Imhof, G. W., *VHF EMC Analysis for User Communications Requirements Study,* ECAC-PR-73-010, ECAC, Annapolis, MD, March 1973.

[3]Klesse, W. R., *UHF EMC Analysis for User Communications Requirements Study,* ECAC-PR-73-047, ECAC, Annapolis, MD, December 1973.

[4]Klesse, W. R., *UHF EMC Analysis for User Communications Requirements Study,* (Supplement 1), ECAC-PR-74-047, ECAC, Annapolis, MD, March 1974.

OBJECTIVE

The objective of this manual is to assist all users in determining applicability of the TCAP to their requirements and to identify required program input data. In addition, the procedural information necessary to run the TCAP at the ECAC computer facility is provided.

GENERAL DESCRIPTION

For a given deployment of tactical communications equipments, the Tactical Communications Analysis Program (TCAP) develops a matrix of the minimum channel (frequency) separations required between each and every net of the deployment to maintain acceptable communications quality. (A net is defined as a group of equipments which communicate with each other on a common frequency.) The program computes the intra-net desired signal-to-receiver sensitivity ratio (S/R_s) and inter-net signal-to-interference ratio (S/I). These ratios are compared with threshold criteria of S/R_s and S/I established by the user as necessary to provide acceptable communications. Based on the frequency-dependent rejection (FDR) characteristics of the equipments, frequency separations are determined that produce sufficient rejection of the interfering signals to meet the S/I criteria. The program provides the capability for the user to specify general terrain types for use in the propagation loss calculations.

The program requires that the equipments be grouped and categorized by types, based on characteristics of transmitter power, receiver sensitivity, antenna gain, cosite antenna gain, antenna height, emission spectra, and receiver selectivity. The FDR curves must also be provided for each transmitter-type/receiver-type pair.

Deployment information must include individual equipment locations, transmitter type, receiver type, net identification, antenna housing identification, and, for airborne equipments, the aircraft type and antenna locations on the airframe. Special equipments, such as point-to-point multiplex and satellite earth stations, which transmit and receive on different frequencies, must be identified.

The channel-separation matrix produced by the program is formed on an equipment-to-equipment basis and is reduced to a net-to-net matrix by retention of the largest equipment-to-equipment frequency separation for each net pair. The matrix is designed as an input to the ECAC Multiple Channel Assignment System (MCAS), for creation of frequency assignments. It may also be used to determine whether an existing frequency assignment provides adequate separations.

CAPABILITIES AND LIMITATIONS

Deployment Types

The TCAP can handle deployments of combined airborne and ground communications equipments (including tactical UHF satellite earth-station equipments) operating in the HF, VHF, and UHF bands. Analysis of the HF band is limited to groundwave mode of operation only. However, the frequency bands of operation cannot be mixed in a given run of the program. Options are available to consider both ground-to-ground and air-to-ground communications or air-to-ground communications only, for the desired signal links. Air-to-air interactions are only considered to the extent of preventing co-channel operation (channel separation of zero) between nets containing aircraft. If satellite tactical communications earth stations are included in the deployment, they must be associated with a satellite system having a hard limiter type transfer function

and must be in geostationary orbit, such as the tactical Fleet Satellite Communications System (FLTSATCOM).[5]

DATA LIMITS

The program is currently limited to 1300 equipments in the deployment with up to 20 different types of equipments. Up to six aircraft types are permitted.

[5]Groot, Paul, et. al., *EMC of FLTSATCOM/AFSATCOM Frequency Plan With Worldwide Environment (TASK 2)* (U) Volumes 1 and 2, ESD-TR-73-034, ECAC, Annapolis, MD, November 1973.

SECTION 2
PROGRAM THEORY

INTRODUCTION

The TCAP develops the minimum frequency separations required for acceptable communications between communications nets, based on ground equipment geographic locations, aircraft position, threshold signal-to-interference ratio, and the adjacent-signal characteristics of the equipments. The potential effects of spurious emissions and responses can be handled by the appropriate choice of limits on the emission spectra/receiver selectivities used to create the FDR curves. The effects of intermodulation can be avoided by the use of intermodulation-free frequency lists, if the output separation matrix is to be used to create a frequency assignment.

For non-collocated equipment pairs, the actual weakest desired signal level reaching the receiver is used in the S/I computation. For cosite interactions, a desired signal level at the threshold value of signal-to-receiver sensitivity ratio (S/R_s) is used, thereby establishing cosite guardbands for the weakest acceptable signal-level case.

Free-space propagation losses are used for air-to-ground and satellite-to-ground signal level computations. The non-collocated ground-to-ground propagation model used in TCAP is the Empirical Propagation Model-73 (EPM-73).[6] This model, which represents the results of a best-fit analysis of measured data, computes a statistical estimate of the mean propagation loss over the terrain type

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[6] Lustgarten, M. and Cohen, D., *Extension of an EMC Propagation Loss Model (EPM-73)*, ECAC-TN-73-25, ECAC, Annapolis, MD, October 1973.

specified by the user. Mainbeam antenna gains and a single user-selected frequency are used for all path-loss calculations.

If two mutually interfering equipments are collocated and the antennas of the interfering equipments are not housed in the same enclosure, the cosite coupling loss model[7] is employed. The co-site coupling model uses two user-specified frequencies to calculate high- and low-band coupling losses and the resulting required cosite frequency separations (guardbands). If the collocated equipments have antennas in a common housing, the antenna isolation factor, specified by the user for the equipment types involved, replaces the coupling loss used in the determination of guardbands.

ASSUMPTIONS AND LIMITATIONS

The following assumptions and limitations apply to the TCAP analysis.

1. Air-to-air interactions are not considered.
2. Satellite systems used in the deployment will closely resemble the tactical Fleet Satellite Communications System (FLTSATCOM) in that the satellite itself will be in geostationary orbit, will have hard-limiter transfer characteristics for the 2-signal case, and will have a maximum power output that does not exceed the FLTSATCOM satellite maximum power output by more than 10 dB. Uplink/downlink frequency separations must also be similar to FLTSATCOM.
3. Satellite earth station-to-earth station interference (direct or via satellite) is negligible, based on FLTSATCOM equipment characteristics and uplink/downlink frequency configurations.

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[7] Madison, J. A., *Extension of the Cosite Coupling Model for Communications Analysis,* ECAC-TN-71-30, ECAC, Annapolis, MD, May 1971.

4. All satellite earth-station communications are via the satellite. Ground-to-ground earth-station communications are not used.

5. Interference from satellite-to-airborne/ground tactical communications equipments is negligible since, based on FLTSATCOM satellite effective radiated power, the signal reaching the vicinity of the earth's surface (-115 dBm) is below nominal UHF receiver sensitivity (-95 dBm) for these equipments (Reference 5).

6. UHF airborne equipments can be transmitting anywhere in the deployment at any time. VHF airborne equipments are normally used in the vicinity of aircraft landing zones.

7. Only the groundwave mode of operation is considered for HF (2-30 MHz) band.

COMPUTED PARAMETERS

In the process of generating the frequency-separation matrix, the TCAP computes the value of the following variables:

1. PLOSS, the propagation loss in dB between every equipment pair in the deployment. PLOSS is needed to compute desired and interfering signal levels.

2. S_{MIN}, the weakest desired signal level in dBm at each communications equipment receiver in the deployment. S_{MIN} is used to determine the most pessimistic desired signal-to-interfering signal ratio (S/I) at each equipment for a given interferer.

3. S/R_S, the desired signal-to-receiver sensitivity ratio in dB for each intra-net equipment combination in the deployment. This is used to determine if all desired communications links meet the threshold S/R_S specified by the user as required to ensure usable communications.

4. I, the effective input on-tune interference power level in dBm for each inter-net equipment combination. This value is needed in the computation of S/I between the equipments.

5. $(S/I)_{MINSAT}$, the minimum acceptable value of S/I in dB at the input to the satellite receiver. This value, when processed by the satellite transfer function, will produce an S/I at the satellite earth station that will meet the threshold ratio of S/I necessary for satisfactory communications.

6. FDR, the frequency-dependent rejection in dB required between each inter-net equipment pair to increase the S_{MIN}/I to the threshold value.

7. Δf, the minimum frequency separation in number of channels required between each inter-net equipment pair to prevent unacceptable adjacent-signal interference.

8. CUPLOS, the magnitude of the path loss in dB between two specific antennas on an airframe. The airframe may be conical such as an attack aircraft or irregular in shape such as a helicopter.

Some of these parameters are discussed later in greater detail including the data and equations used in their computation.

WEAKEST DESIRED SIGNAL (S_{MIN})

All desired (intra-net) signal levels at the input to each receiver are determined and the minimum signal level is retained for S_{MIN}. If the air-to-ground option is chosen, only air-to-ground intra-net signals are considered at the ground receivers.

The desired signal levels are calculated using the following equation:

$$S_R = P_T + G_R + G_T - PLOSS \qquad (1)$$

where

S_R = the desired signal level at a receiver, in dBm

P_T = power emitted by an intra-net transmitter, in dBm

G_R = antenna gain of receiver, in dBi

G_T = antenna gain of transmitter, in dBi

PLOSS = propagation loss between the transmitter and receiver, in dB.

S_{MIN} = the minimum value of all S_R's calculated at a given receiver. (2)

If the receiver under consideration is a satellite earth station, then, as a result of assumption 4 on page 7 , the only desired signal, and therefore, the minimum desired signal reaching the receiver, is the signal from the satellite. For this special case, Equation 1 becomes:

$$S_{MIN} = S_{MINSTA} = (ERP)_{SAT} + G_R - PLOSS - L_F \qquad (3)$$

where

S_{MINSTA} = minimum desired signal reaching the satellite earth-station receiver, in dBm

$(ERP)_{SAT}$ = minimum effective radiated power of satellite (satellite transmitter power plus antenna gain), in dBm

G_R = satellite earth-station receiver antenna gain, in dBi

PLOSS = propagation path loss from geostationary satellite to vicinity of earth surface, 175 dB

L_F = fading loss from the satellite to vicinity of earth surface, 3 dB.

For the satellite receiver, the anticipated weakest desired signal reaching the satellite is used:

$$S_{SAT} = (ERP)_D - PLOSS - L_F + G_{SAT} \quad (4)$$

where

S_{SAT} = weakest desired signal reaching satellite, in dBm

$(ERP)_D$ = anticipated minimum desired effective radiated power (transmitter power plus antenna gain) used by earth stations on channels associated with the deployment, in dBm

PLOSS = propagation loss between satellite and the vicinity of earth's surface, 175 dB

G_{SAT} = satellite receiver antenna gain, in dBi

L_F = fading loss between satellite and the vicinity of earth's surface, 3 dB.

DESIRED SIGNAL-TO-RECEIVER SENSITIVITY RATIO (S/R_S)

In addition to the computation of minimum signal levels received at each equipment in the deployment, the desired signal-to-receiver sensitivity ratio (S/R_S) is calculated for each intra-net

equipment combination. That is, at each equipment receiver, the S/R_s is computed from every other equipment transmitter in the same net. If any of the S/R_s's computed in this way are less than the threshold value established by the user for satisfactory communications, an error message is printed identifying each failure, the equipments involved, computed S/R_s's and threshold S/R_s. The program then proceeds to compute inter-net interference.

ADJACENT-SIGNAL INTERFERENCE POWER LEVEL (I)

Configurations that illustrate adjacent-signal interference possibilities for tactical communications equipments and satellite earth stations are shown in Figures 1 through 9. Assumptions 3 and 5 presented on page 7 eliminate Figures 1, 2, 3, 5 and 7 from consideration, since, based on FLTSATCOM analyses, earth station-to-earth station interference is nonexistent and interfering signal levels at the earth's surface are below tactical equipment receiver sensitivities and are therefore not detected.

The interference configurations not eliminated fall into two categories:

1. Direct interference
2. Indirect interference (via satellite).

The equations defining the two categories of interference are developed in the next paragraph which addresses signal-to-interference computation.

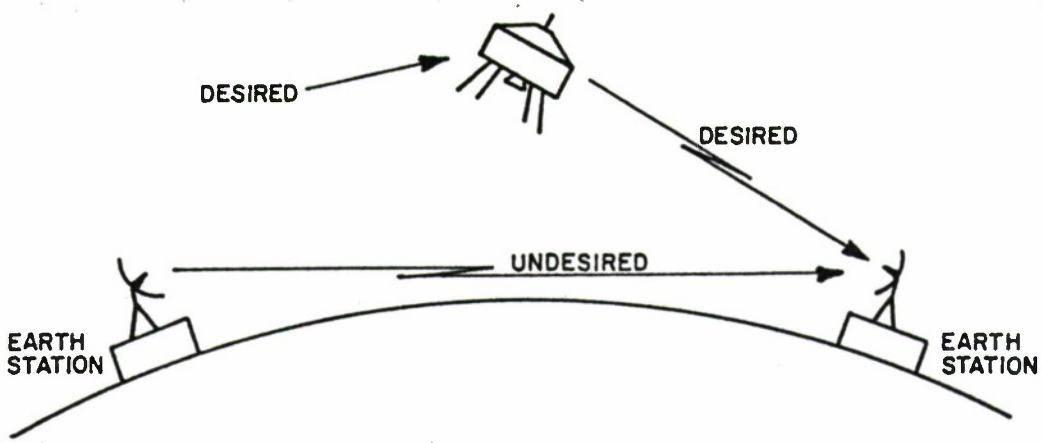

Figure 1. Earth station-to-earth station interference (direct).

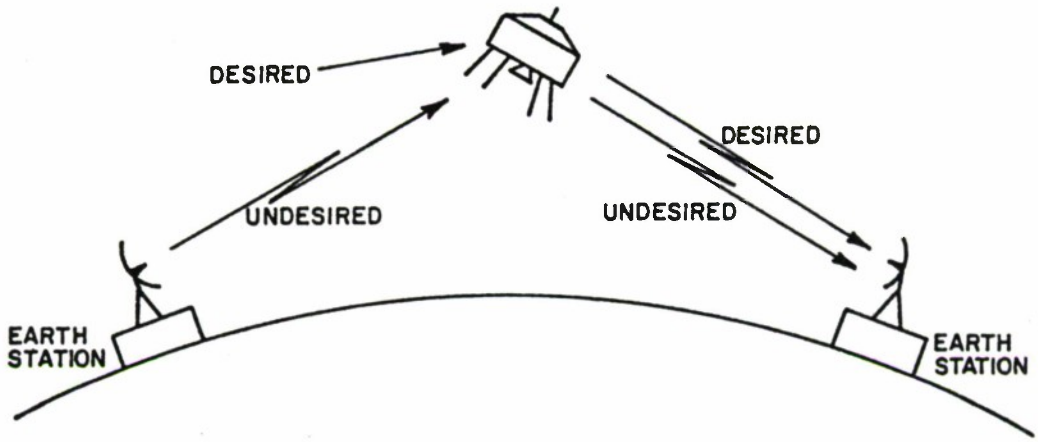

Figure 2. Earth station-to-earth station interference (via satellite, adjacent channels).

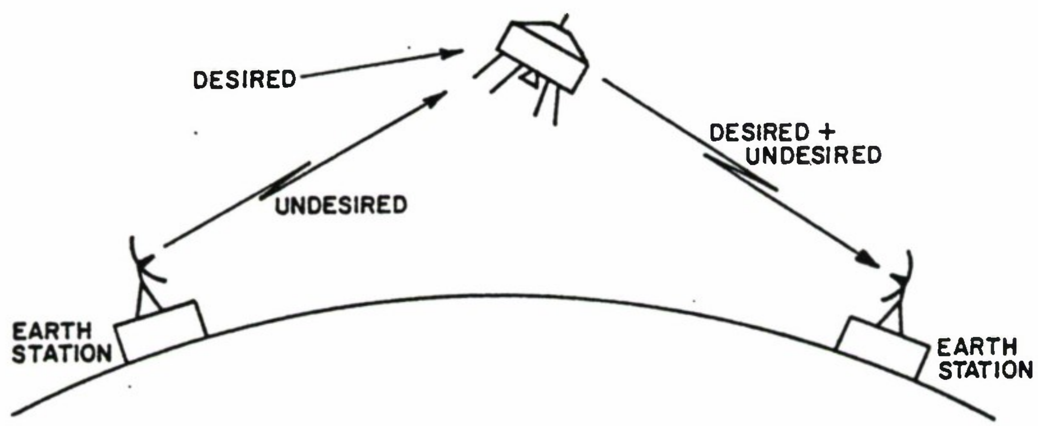

Figure 3. Earth station-to-earth station interference (via satellite, single channel).

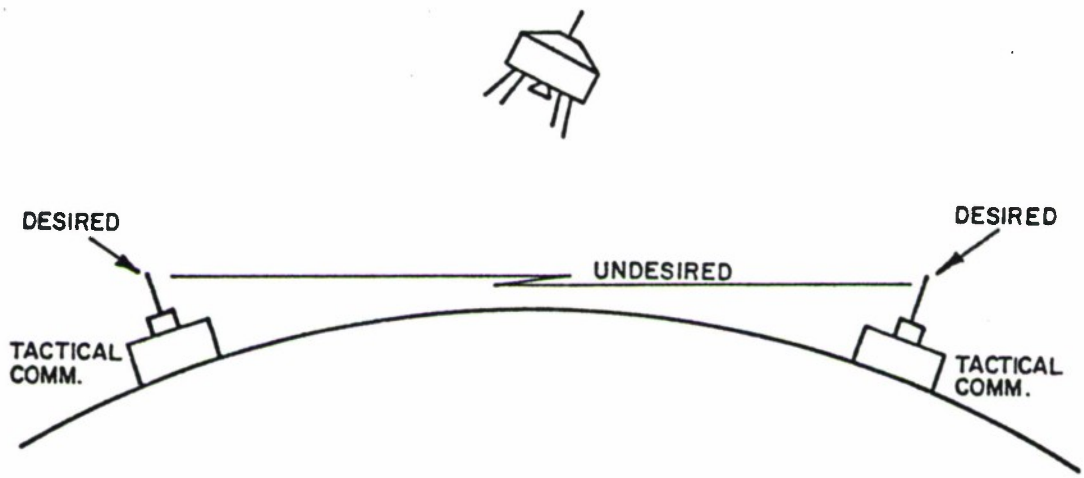

Figure 4. Communications-to-communications equipment interference (direct).

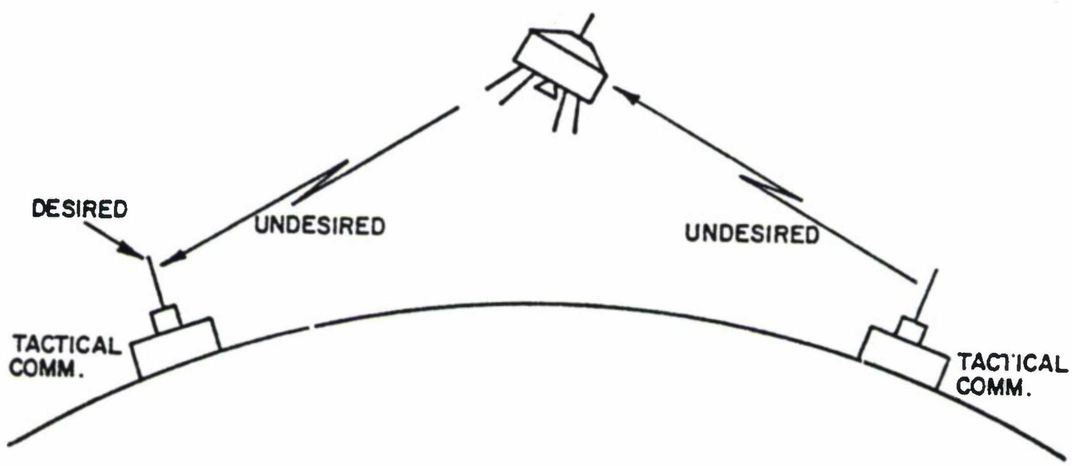

Figure 5. Communications-to-communications equipment interference (via satellite).

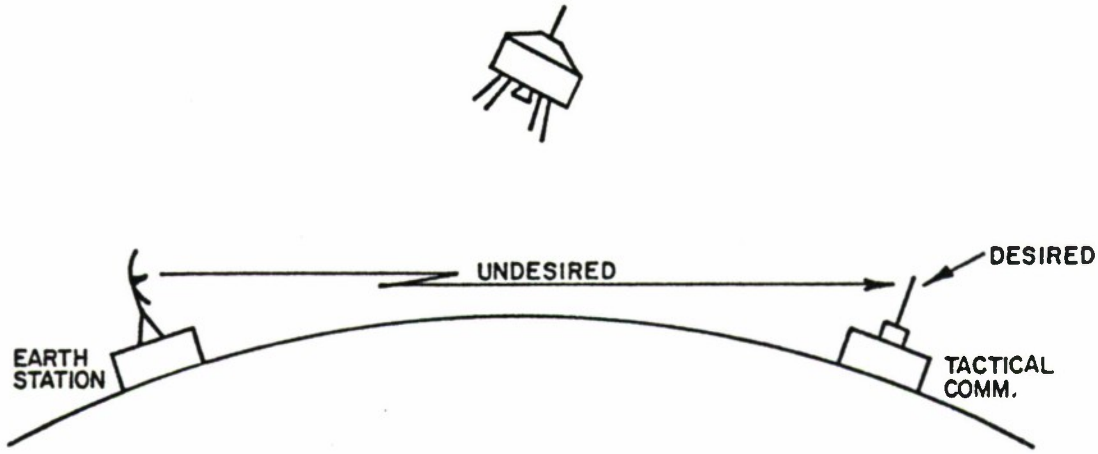

Figure 6. Earth station-to-communications equipment interference (direct).

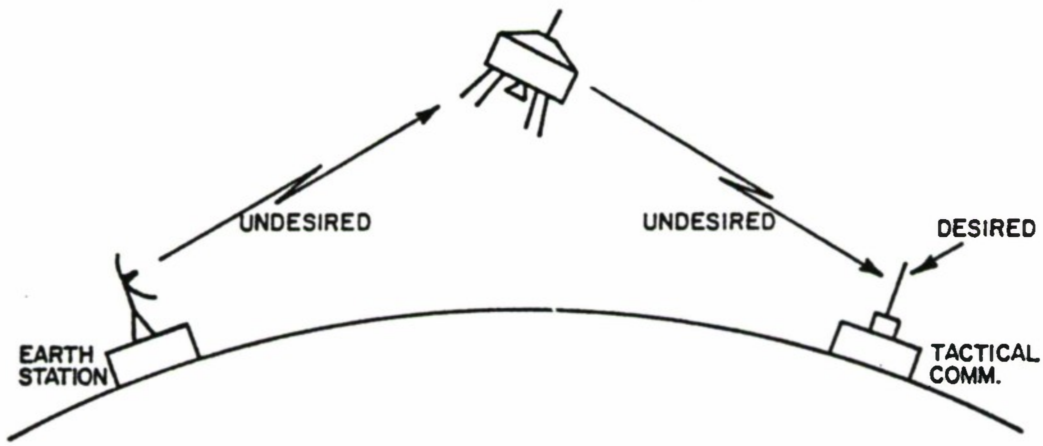

Figure 7. Earth station-to-communications equipment interference (via satellite).

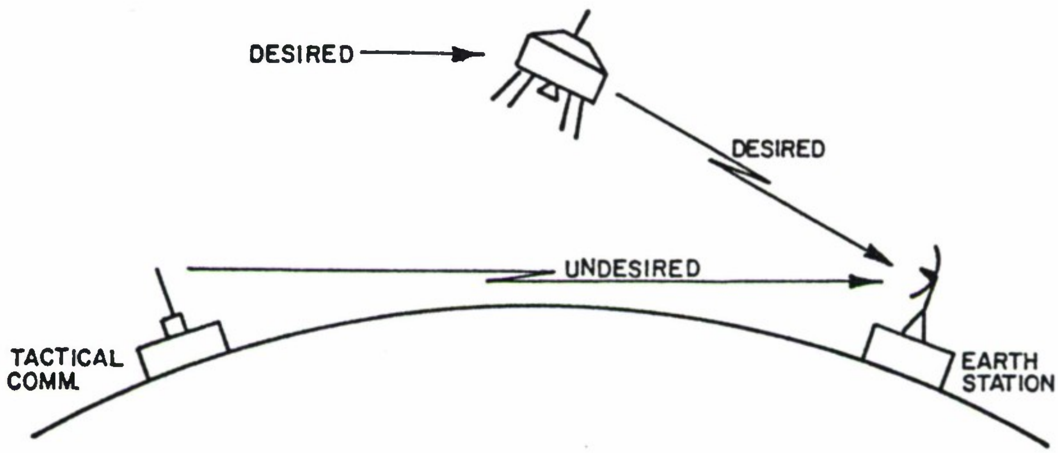

Figure 8. Communications equipment-to-earth station interference (direct).

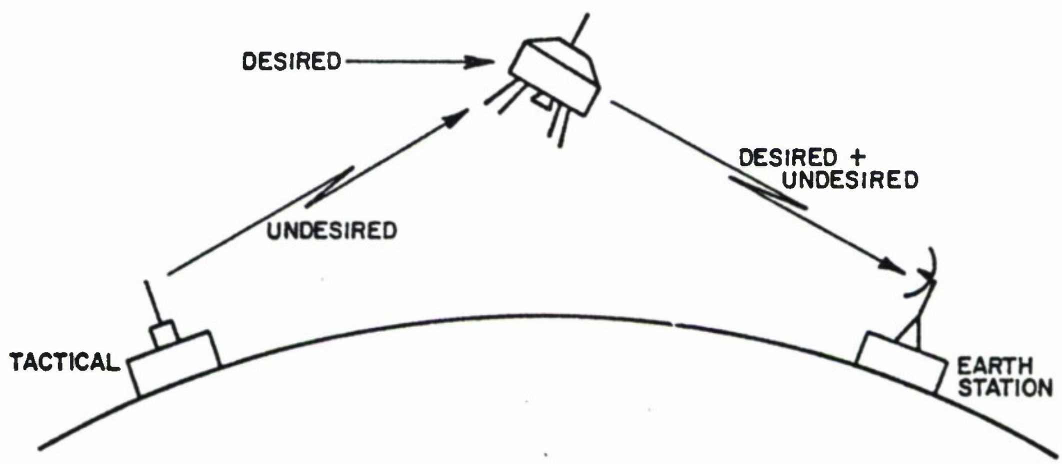

Figure 9. Communications equipment-to-earth station interference (via satellite).

Direct Interference

Adjacent-signal interference signal levels between non-collocated equipments of different nets, which are needed for the determination of input S/I's are computed using the equation:

$$I = P_I - FDR - PLOSS + G_R + G_I - L_C \qquad (5)$$

where

I = the signal level at the desired receiver due to the interfering transmitter, in dBm

P_I = power of interfering transmitter, in dBm

G_I = antenna gain of the interfering transmitter, in dBi

G_R = receiver antenna gain, in dBi

PLOSS = propagation loss between the receiver and the transmitter, in dB

FDR = frequency-dependent rejection between the receiver and transmitter, in dB

L_C = cross-polarization loss, in dB.

Direct Signal-to-Interference Ratio (S/I)

The signal-to-interference (S/I) ratio at a given receiver must always equal or exceed the threshold value (S/I_{MIN}) for adjacent channel interference to be maintained at an acceptable level. Therefore:

$$S_{MIN} - I \geq (S/I)_{MIN}$$

or rearranging terms:

$$S_{MIN} - I - (S/I)_{MIN} \geq 0 \qquad (6)$$

where

$(S/I)_{MIN}$ = threshold value of desired signal-to-interference ratio, in dB

and all other terms have been defined previously.

Using Equation 5 and Inequality 6:

$$S_{MIN} - (P_I - PLOSS + G_R + G_I - L_C) - (S/I)_{MIN} + FDR \geq 0. \qquad (7)$$

Starting with a zero value of FDR, the FDR is increased until Inequality 7 becomes true. Once the needed FDR is determined, the frequency separation corresponding to this FDR value is retrieved from the stored FDR curves.

The roles of interferer and victim are then reversed and the required FDR is again determined and the corresponding frequency separation is retrieved. The larger of these two frequency separations is retained as the required frequency separation for those two equipments.

Indirect Interference (via satellite) S/I

If satellite earth stations are included in the deployment (UHF band only), then the interference configuration represented by Figure 9 is also possible if either of the two equipments is an earth station. In this case, it is mandatory to determine the S/I input to the satellite that will ensure the S/I reaching the

earth station is equal to or greater than the threshold ratio for the earth station. To accomplish this, it is necessary, by working backwards, to convert the earth-station threshold S/I into a required minimum satellite input S/I, using the hard-limiter transfer function (assumption 2, page 6) illustrated in Figure 10. The transfer function yields the relationship of the (S/I) output for the satellite. However, since both the desired signal and the interfering signal suffer the same degradation and propagation loss from satellite to earth station:

$$(S/I)_{OUTSAT} = (S/I)_{STA} \tag{8}$$

where

$(S/I)_{OUTSAT}$ = output signal-to-interference ratio from the satellite, in dB

$(S/I)_{STA}$ = input signal-to-interference at the satellite earth station, in dB.

Thus, by knowing the required threshold signal-to-interference ratio at the earth station and the satellite transfer function curve, the required threshold signal-to-interference ratio into the satellite $(S/I)_{MINSAT}$ is easily determined.

To compute the actual value of signal-to-interference ratio at the satellite input, Equations 4 and 5 are used.

As was the case in direct interference, the S/I at a given receiver must always exceed the threshold ratio, to avoid interference; therefore, Inequality 6 becomes, for the satellite case:

$$(ERP)_D - L_F - (P_I + G_I) + L_C + FDR - S/I_{MIN} \geq 0. \tag{9}$$

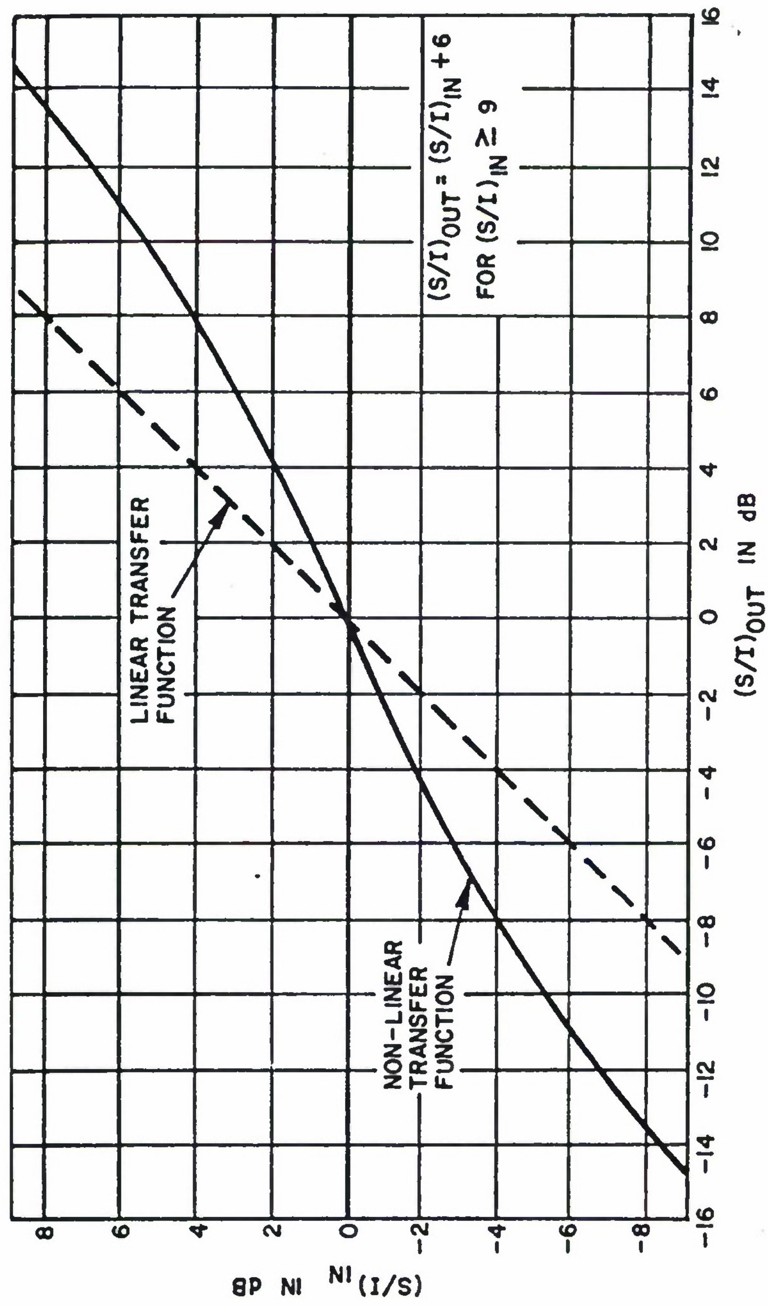

Figure 10. Satellite transfer function (2-signal case).[a]

[a]Reproduced from Reference 5.

As in the direct case, FDR is increased until the above inequality becomes true; at that value of FDR, the frequency separation is interpolated from the FDR curves.

COSITE ANALYSIS

Ground Equipments

Adjacent-signal interference computations for ground cosite conditions include non-linear effects, since these effects become significant at the high interfering signal levels inherent in cosite conditions. For cosite conditions, the adjacent-signal interference becomes:

$$I = P_I - FDR + G_R + G_I - LOSS + (1-M)\ (S_{MIN} - R_S - 5) \quad (10)$$

where

LOSS = cosite coupling loss between the two antennas, or the antenna isolation factor if the antennas are in the same enclosure, in dB

M = constant determined by modulation characteristics and P_I

and all other terms have been defined previously.

With the interference power level thus determined and the acceptable S/I specified, the required frequency separation is determined from the FDR data in the same manner as discussed in the direct interference case above.

Airborne Equipments

In the case of airborne cosite (same aircraft) conditions, there are two possible cases. The first case is when the aircraft may be approximated by a cylindrical section such as an attack aircraft. The second case is when the aircraft is very irregular in shape such as a helicopter.

In the first case, the aircraft path loss routine from AVPAK[8] has been modified for use with TCAP. This routine assumes a tapered cylindrical section for the shape of the fuselage. The dimensions of the aircraft including the length, maximum radius of the fuselage, and the height and angle location of the antennas are supplied by the analyst. These parameters are described in detail in Section 4.

Up to four different losses are calculated and summed as appropriate to the particular antenna configuration on the fuselage. These losses are:

1. Free-Space Loss (L_F). This loss is used when the two antennas are line-of-sight on the airframe.
2. Curvature Path Loss (L_C). This loss is calculated when the path between the antennas is obstructed by the fuselage and is added to L_F.
3. Bulkhead Loss (L_B). When one antenna is located in the nose radome and the second is on the fuselage, L_B is calculated and added to L_F. It is assumed for this calculation that the bulkhead between the radome and the fuselage is a knife-edge obstruction.

[8]Hazeltine, R., *Avionics Interference Prediction Model,* ECAC-TN-75-020, ECAC, Annapolis, MD, September 1975.

4. Airfoil Shading Loss (L_W). When an airfoil such as a wing is located between the two antennas, L_W is calculated. L_W is the sum of the losses in the absence of the airfoil and the free-space loss for the shortest path around the airfoil.

In the case of irregularly shaped airframes such as a helicopter, a different model is used to determine the path loss on the aircraft. This model is called IRAFCO.[9] The model includes a technique to divide a non-cylindrical curved surface into cylindrical segments. The path is divided into straight (line-of-sight) segments, curved segments, and/or knife-edge diffraction segments. An example of such a path is shown in Figure 11. The total path loss is the free-space loss based on the total path length plus the additional losses due to the curved and knife-edge segments.

These values of path loss are then used for the LOSS term in Equation 10 to determine the interference signal level. The determination of the required frequency separations using the S/I ratio and the FDR data proceeds as discussed previously in the direct interference case.

Once the interference is calculated using Equation 10, the determination of S/I and the FDR needed to meet the threshold S/I proceeds as in the direct interference case discussed above.

AIRCRAFT-TO-GROUND ANALYSIS

Since the aircraft are in motion while transmitting and receiving, it is necessary to assume some location for them when determining desired signal and interfering signal levels.

---

[9] King, Bruce, *Path Loss Prediction for Irregularly-Shaped Airframes*, ECAC-TN-76-004, ECAC, Annapolis, MD, February 1976.

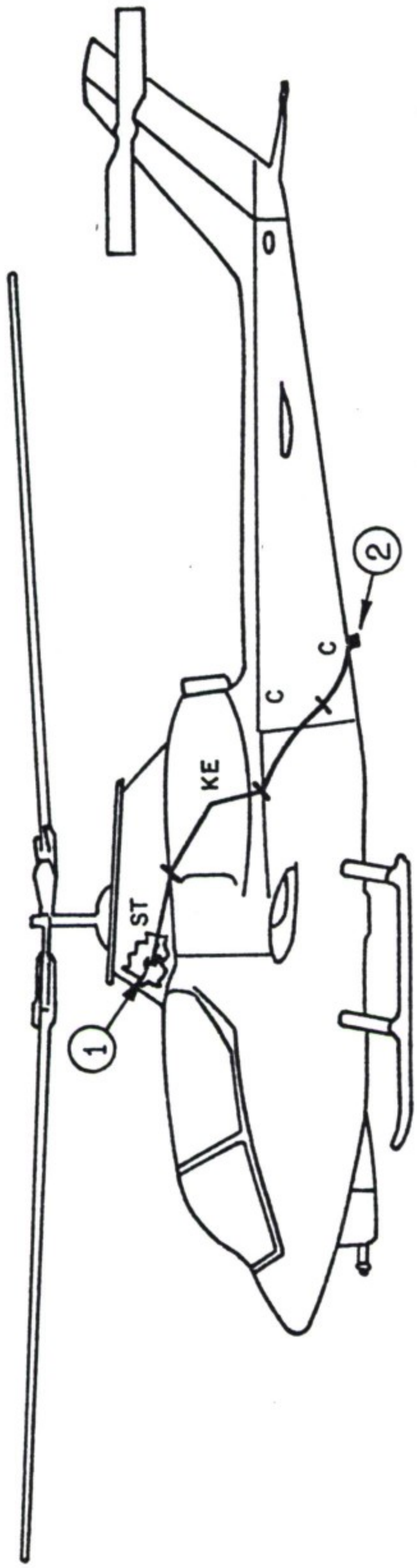

Figure 11. Non-cylindrical curved path between an antenna pair.

For the UHF band, which is used in air superiority and ground support operations, aircraft are assumed to be anywhere in the deployment at any time. Thus, to generate a safe margin for the required frequency separations, the aircraft are placed in positions that yield weakest desired signal levels (at maximum range and altitude) and maximum interfering signal levels (directly overhead of interferer at minimum communications altitude). These distances are used to compute the propagation loss term (PLOSS) in the desired-signal and interference equations.

As in the UHF case, VHF airborne equipments can be placed at the aircraft maximum communications range and altitude for desired signal calculation; however, for interference calculation, the different uses of UHF and VHF equipments must be considered. The VHF nets have much more restrictive functions, such as landing guidance, and are used primarily within a short distance of their landing zones. As a result, the VHF maximum communications ranges for aircraft are, in general, much shorter than they are for UHF. Unlike the UHF case, therefore, the aircraft's maximum VHF communications range from its landing zone may not permit the aircraft to be directly over a potential ground interferer. Thus, the aircraft is assumed to be directly overhead of the ground interferer only if the maximum communications range for the aircraft exceeds the distance between the landing zone and ground interferer (bottom illustration of Figure 12). If the aircraft communications range falls short of the ground interferer's location, the aircraft is placed at the closest possible position of the interference calculations (D_{MAX}, upper illustration of Figure 12).

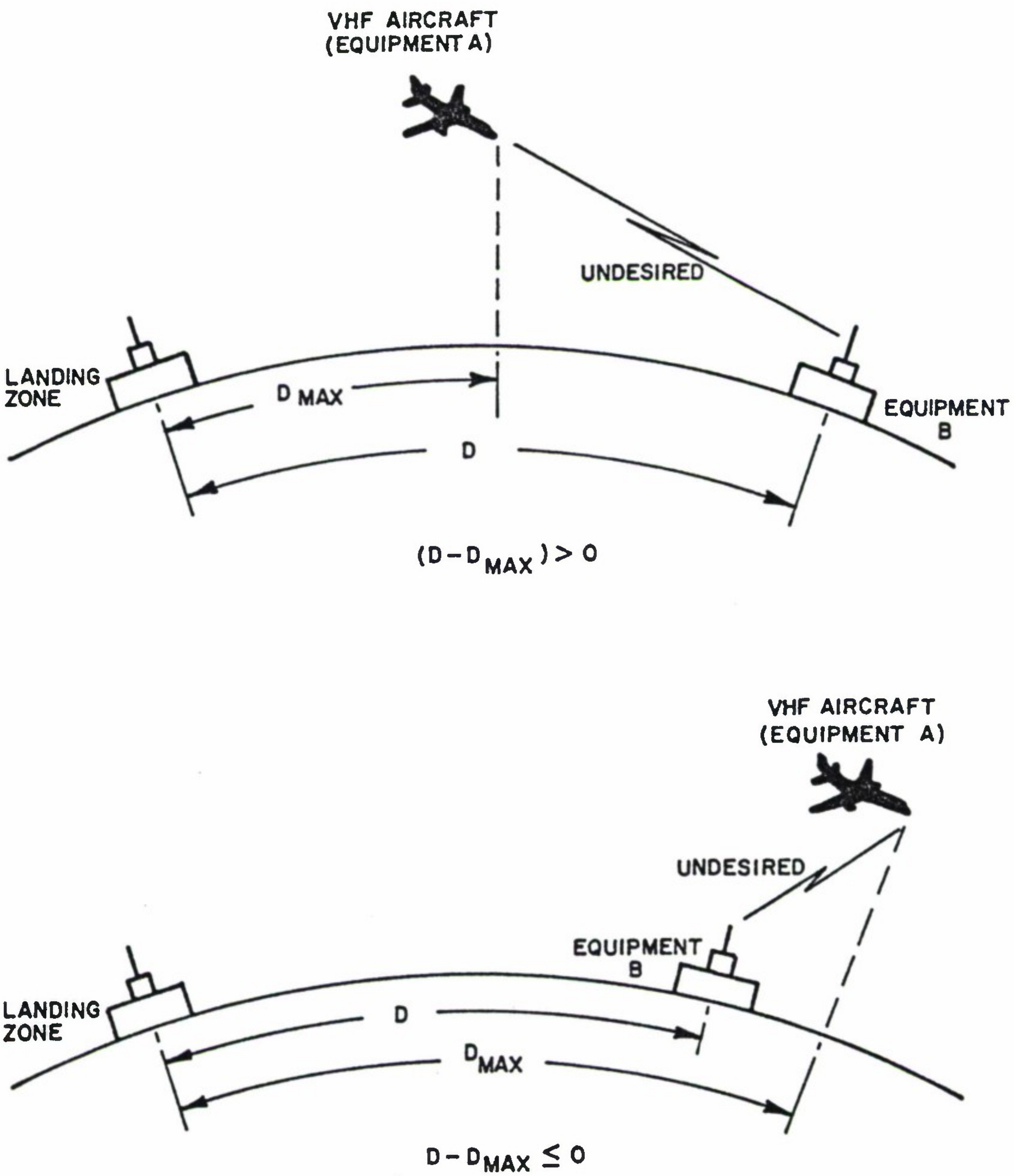

Figure 12. VHF aircraft analysis configuration diagram.

SECTION 3

PROGRAM FLOW CHART

SUMMARY OF PROGRAM FLOW

The flow chart for the TCAP is shown in Figure 13. To assist in understanding the program, a verbal description of the major logic steps of the program is presented here.

The first step of the program is to enter all the required data and program options as described in Section 4 and to store the data in mass storage for use by the program as required. The weakest desired signal level at each equipment in the deployment is determined and is stored for use later in determining the S/I ratio. This signal level is also an input to a mass storage file for use later with the histogram plot program.

Each equipment is then checked in turn against all other equipments in the deployment. The procedure for one equipment pair will be described as the same procedure is used for all pairs.

The equipment pair is checked to determine if both are airborne as the program is not concerned with air-to-air considerations. If both are airborne, the channel separation is arbitrarily set to 2 channels so that co-channel or adjacent-channel operation will not occur. The equipment pair is then skipped from further analysis. If both equipments are satellite earth centrals, they are also skipped in accordance with assumption 3, page 6 .

If the equipment pair is not both airborne or both satellite centrals, it will fall into one of two categories. The equipment pair will either be in the same net or in different nets.

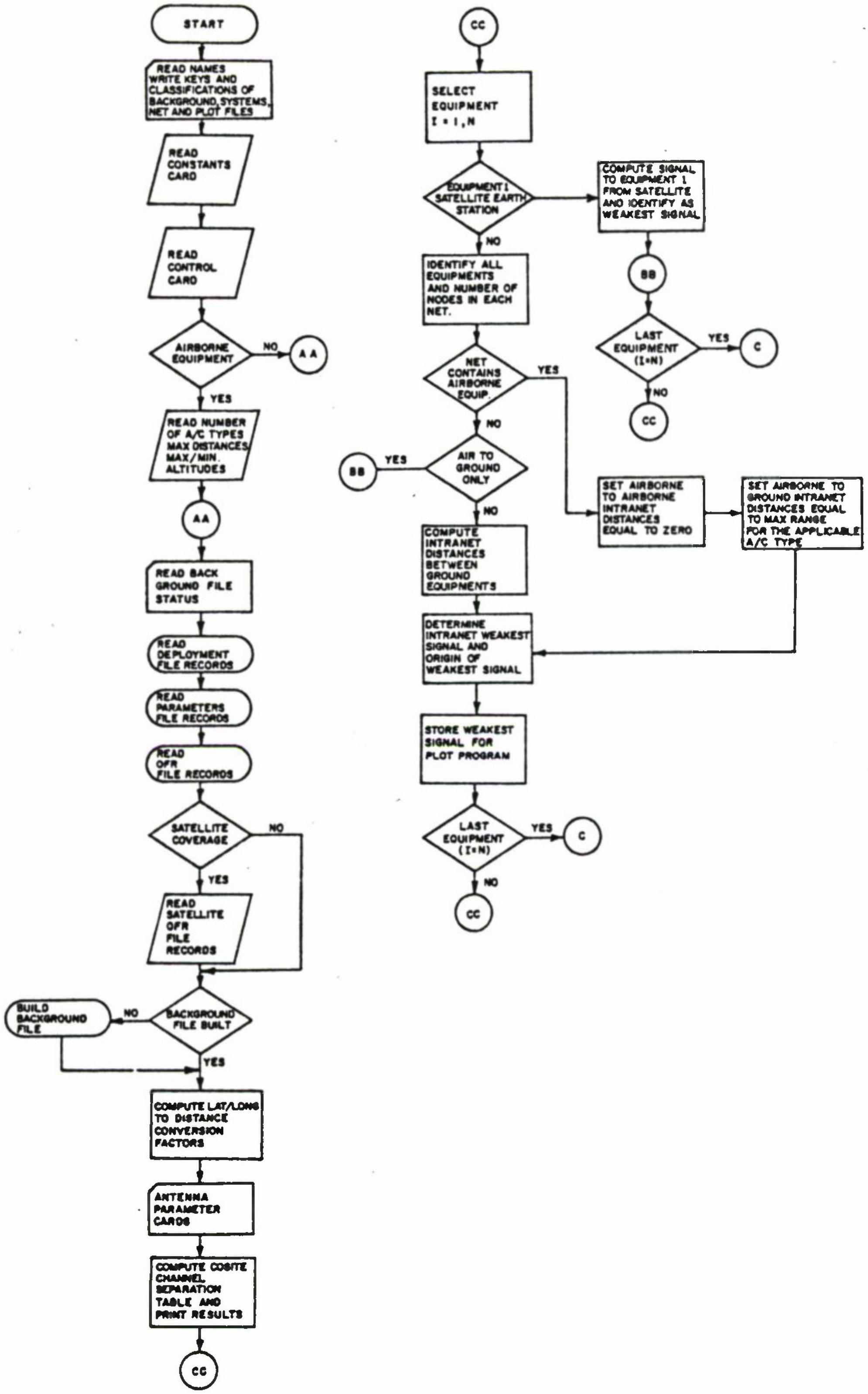

Figure 13. TCAP flow chart.
(Page 1 of 3)

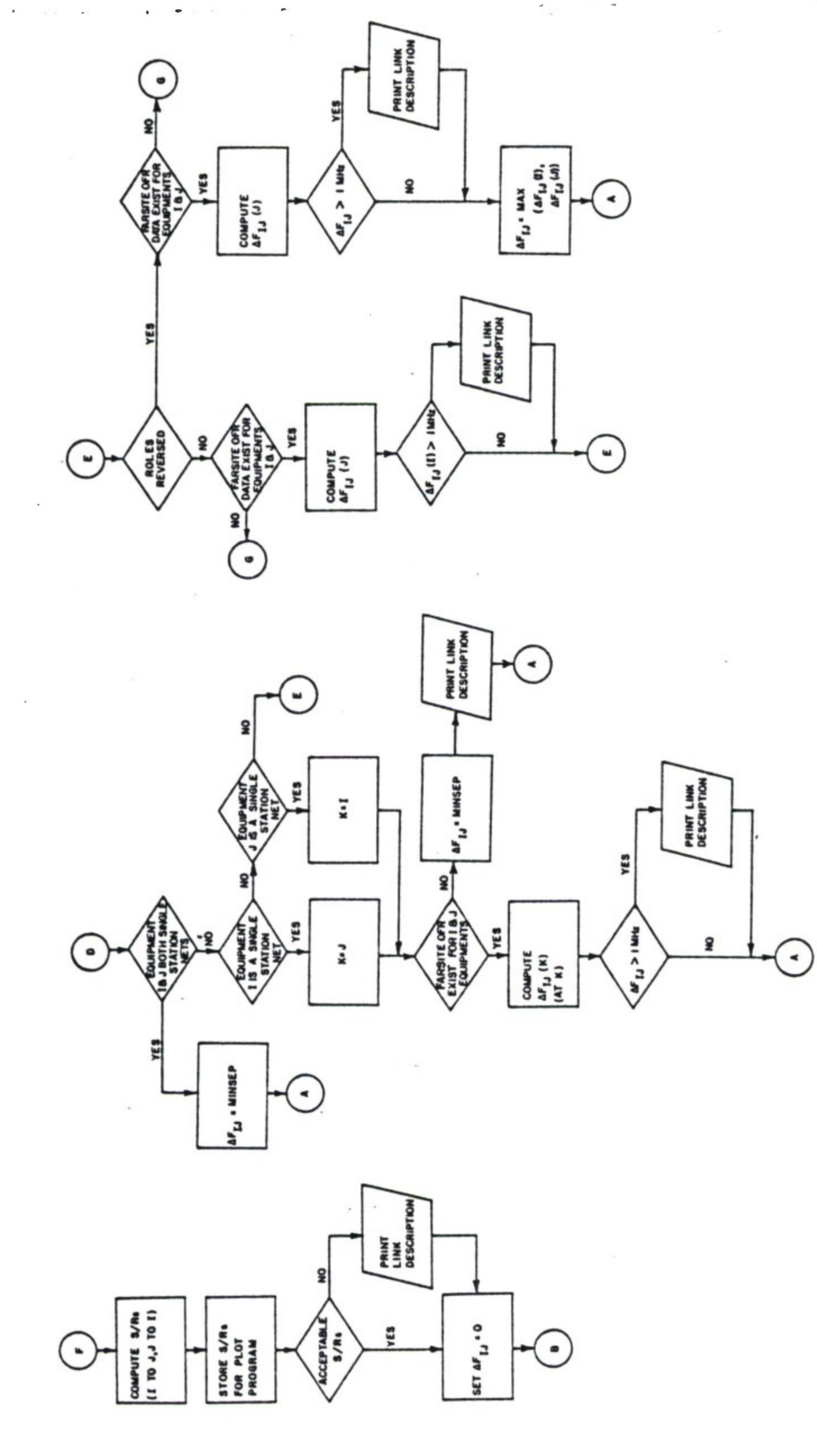

Figure 13. (Page 2 of 3)

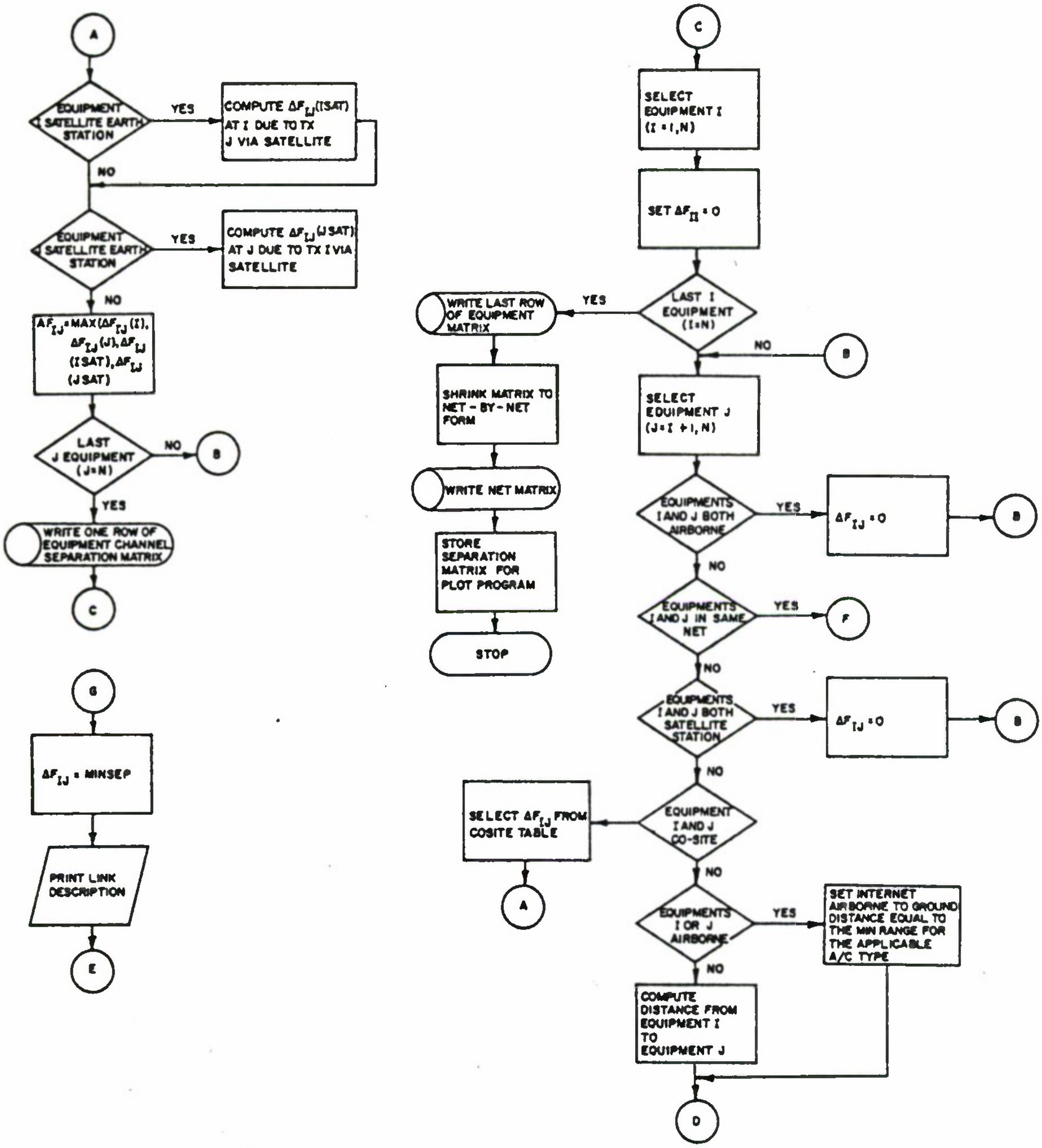

Figure 13. (Page 3 of 3)

For the case of both equipments in the same net, the required frequency separation is set to zero in accordance with the definition of a net. The signal-to-receiver sensitivity (S/R_s) ratio is calculated and compared with the minimum acceptable S/R_s provided for that particular receiver. If the S/R_s value is too small, a description of that link is provided as an output to the analyst for corrective action. The S/R_s values are also stored on mass storage for later use by the plot program.

If the equipments are not in the same net, they are checked to see if they are collocated. If they are collocated, the required frequency separation is determined from the cosite analysis described previously and the next equipment is selected. If the two particular equipments being examined are not collocated, the weakest desired signal terminating at the first equipment is retrieved as the desired signal level. The interfering signal level at the first equipment, due to emissions from the second equipment, is determined. The S/I based on these two values is computed and compared with the minimum acceptable S/I. If the interference level is too high, the FDR curves are examined and the amount of off-tuning required to reduce the interfering signal to an acceptable level is determined. The amount of off-tuning required is the minimum frequency separation required to prevent equipment Two from interfering with equipment One.

The roles of the first and second equipments are then reversed and the frequency separation required to prevent equipment One from interfering with equipment Two is determined. The larger of the two frequency separations is stored as the required separation for the two equipments.

This procedure is repeated until required separations have been determined for all possible equipment combinations. Generally, a very large required-frequency-separation matrix is generated on an equipment-by-equipment basis for all equipments in the deployment.

One net may consist of many equipments. Since all equipments in the net use the same frequency, all are restricted by the largest required separation for any equipment in the net. Thus, the required-frequency-separation matrix is reduced from an equipment-by-equipment matrix to a net-by-net separation matrix, based on the largest separation for each pair of nets. This net-by-net matrix is then stored on mass storage for possible future use and also is printed for use by the analyst. The separation matrix is also stored for use by the plot program.

SECTION 4

PROGRAM INPUTS

INPUT CATEGORIES

Many of the inputs discussed below are available at ECAC. The outside user should confer with ECAC to determine availability of information on the particular communications systems and on deployments planned for analysis by the TCAP. The required inputs for TCAP fall into six categories:

1. Program options
2. Equipment characteristics
3. Deployment configuration
4. Threshold parameters
5. Aircraft parameters
6. Special satellite parameters.

The exact format for the inputs is provided in Section 6.

PROGRAM OPTIONS

The following options are offered by TCAP:

1. Deployment terrain type: sea water, marshy land, average land, plains or desert (types 1, 2, 3, 4, and 5 respectively). This option specifies the general terrain type for a given run to be used with the path loss routine.

2. Deployment aircraft: aircraft in the deployment or no aircraft. This option reduces the data input requirements when aircraft are not included.

3. Satellite centrals: centrals are or are not included in the deployment (UHF only). This option reduces input requirements and some calculations when satellite centrals are not included.

4. Link types: both air-to-ground and ground-to-ground, or air-to-ground only. This option would be useful for some applications where the UHF band is used for air-to-ground only.

5. Channel width: the width of a channel (in kHz) to be used during a given run of the program. The output separation matrix is given in number of channels.

6. Plot: histogram plots of minimum desired signal levels and S/R_s values for each equipment and the frequency separation matrix may or may not be obtained.

EQUIPMENT CHARACTERISTICS

The TCAP requires that the analyst sort the equipments used in the deployment into categories of transmitters and receivers having similar power output, antenna gains, receiver sensitivities, and antenna sidelobe characteristics. These categories are assigned type numbers. The following information is required for each transmitter and receiver type:

Transmitter	Receiver
Power (dBm)	Sensitivity (dBm)
Antenna gain (dBi)	Antenna gain (dBi)
Cosite Antenna gain (dBi)[a]	Cosite antenna gain (dBi)[a]
Antenna height (ft)	Antenna height (ft)
Antenna polarization	Antenna polarization
Emission spectra	Relative selectivity.

[a]Always supplied by ECAC as part of the Cosite Coupling Model.

Transmitter relative emission spectrum and receiver relative selectivity are not required if FDR curves (10 data point pairs assumed symmetrical about the on-tune frequency) are supplied for each transmitter type/receiver type. If these curves are not supplied, a separate ECAC program (OFRCAL)[10] is used to generate the FDR's from the emission spectra and selectivities. The emission spectra and selectivities may be given as data points or slope falloffs (dB/decade) or a combination of the two. If antenna couplers or other system frequency-filtering devices are used, their filtering effects must be incorporated into the emission spectra and selectivities. Preamp gains should be added to the antenna gains. The necessary equipment characteristics, including FDR's, are already available at ECAC for most Marine Corps UHF/VHF communications systems.

In addition, for each transmitter-type to receiver-type pair in the deployment, a closest expected cosite antenna separation distance must be supplied. If the possibility exists that the antennas of the pair are housed in the same enclosure, an isolation factor between the antennas must also be supplied.

DEPLOYMENT CONFIGURATION

For each equipment, the following deployment information is needed to create the required input Deployment File for the TCAP:

Latitude (not required for airborne equipment)
Longitude (not required for airborne equipment)
Net identification
Unit identification (optional)
Transmitter type

[10]Harris, Robert, *OFR And F-D Analysis With Program OFRCAL,* ECAC-TN-71-25, ECAC, Annapolis, MD, September 1971.

Receiver type

Aircraft type (airborne equipment only)

Satellite earth central identifier (if satellites included)

Antenna enclosure identifier

Frequency resource list number (optional)

Antenna locations on aircraft (if aircraft included).

The net and unit identifications are 6-character (or less) names, used to uniquely identify each communication net (equipments which communicate with one another) and each organizational unit in the deployment. The transmitter/receiver types are coded numbers used to identify each category of transmitter and receiver, based on the characteristics mentioned previously. The types of aircraft in the deployment must also be numbered-coded (1, 2, 3, etc.) to permit proper association of airborne equipment with aircraft, since aircraft differ in range, altitude, and function. Aircraft equipments used in multiple nets are multi-entry items in the file with only net identification changing from entry to entry. Satellite earth-station equipments are coded "S" so that they may be properly handled in the program. The antenna enclosure identifier is a number used to associate equipments that are in the same van and have antennas in a common housing. Each antenna housing in the deployment that contains antennas for more than one equipment is assigned a number; the need for this coding is explained in the discussion of cosite conditions (page 6).

Frequency resource lists are required only if the user desires to generate a specific frequency assignment after the TCAP produces the channel-separation matrix. Each list must be numbered and each equipment in the deployment must be associated with one of the lists

via the list number. The TCAP develops a background file that relates equipment to applicable resource lists and indicates the net order of the required frequency separation matrix. The matrix and background file can be entered into the MCAS (Multiple Channel Assignment System), one of ECAC's frequency-assignment programs, for creation of a specific frequency assignment. After possible reformatting, the matrix could be used with almost any frequency-assignment system.

The antenna locations on the aircraft must be provided for use with the aircraft cosite path loss routine. If the path losses have been calculated previously, it is not necessary to do them again. Path losses for the VHF and UHF antennas for the following aircraft have been calculated and are available at ECAC:

F-4J, N	A-6E	OV-10A
A-4	EA-6B	F-14.

THRESHOLD PARAMETERS

As explained in Section 3, the minimum acceptable desired signal-to-receiver sensitivity ratio (S/R_s) and the minimum acceptable desired signal-to-interference ratio (S/I) are required inputs to TCAP that must be supplied by the analyst.

As an example, an S/R_s = 5 dB and an S/I = 24 dB for typical UHF AM communications equipments will yield an articulation score of 85%. This score is usually considered marginal but usable and thus these values would be a good choice for the minimum acceptable ones.

A channel separation recovery value is required by TCAP. This value is assigned to the separation matrix as a default option. This value would be used in the event FDR values were not supplied or if a net should happen to have only one equipment.

A value of frequency is required for use by the propagation routine in calculating the path loss. This is usually the middle of the frequency band of concern. For military VHF (30-76 MHz), a value of 53 MHz is chosen whereas for the UHF (225-400 MHz) band, a value of 310 is used. The choice of the midband minimizes the deviation over the band.

Quite often the response characteristics of an equipment are not constant over the band of operation. Therefore, the FDR values would not be the same for the entire band. To allow for this in the cosite case where it may be important, two cosite guardbands are calculated and an average value is stored for use by the program. The starting frequency for both the lower and upper guardband must be provided. These numbers are typically the lower band edge and the midband point.

AIRCRAFT PARAMETERS

To position the airborne equipment for a "worst-case analysis," the various aircraft of the deployment must be identified in terms of their communications ranges and altitudes. Required input to the TCAP is the identification of each aircraft by a numeric type (1, 2, 3, etc.). For each aircraft type, a typical maximum communication range together with a maximum and a minimum communications altitude are entered. The maximum values are used to compute the desired signal-to-receiver sensitivity ratio between airborne equipments and ground equipments of the same net.

The minimum altitude value is used to compute the inter-net undesired signal and signal-to-interference ratio between airborne and ground equipments of different nets. Since the aircraft can be anywhere in the deployment at any time (if their maximum communication range permits), the interfering case usually places the aircraft directly overhead of the interferer (minimum range = 0) at the minimum altitude (see Figure 12, bottom illustration). For example, an attack aircraft could typically be transmitting and receiving at zero range (overhead) and at an altitude of 2000 feet; an intercept aircraft would perform most communications above 10,000 feet.

SPECIAL SATELLITE PARAMETERS

In addition to the equipment characteristics necessary for all equipments in the deployment, as outlined on page 34, two special parameters are required if satellite tactical communications are to be considered. The first parameter is the minimum effective radiated power (transmitter power plus antenna gain) emanating from the satellite. The second parameter is the weakest anticipated effective radiated power to be transmitted to the satellite. The first is used to determine the desired signal level reaching the satellite's earth stations, and the second is used in the computation of the signal-to-interference ratio reaching the satellite.

SECTION 5

OUTPUT

OUTPUT CATEGORIES

The outputs of the TCAP fall into five categories:

1. Failure messages
2. Cosite guardband tables
3. Background file
4. Channel separation matrix
5. Plots.

FAILURE MESSAGES

The failure messages identify nets, units, transmitter types, receiver types, and the nature of the failure. The failures identified by TCAP are:

1. S/R_S insufficient to meet threshold ratio. The message includes the threshold and computed ratios.

2. No value for cosite guardband. Message includes recovery value of frequency separation used as the required guardband.

3. Insufficient FDR available to ensure S/I greater than the threshold ratio. The FDR value used (limit of FDR curve) is included in the message.

4. Required frequency separation exceeds 20 MHz. Message includes the value of separation required.

COSITE GUARDBAND TABLE

For each transmitter-type/receiver-type pair in the deployment, cosite guardbands for the high and low portions of the frequency band and an average cosite guardband (required frequency separation for acceptable communications), are computed and printed in tabular form. For each pair, the guardbands are computed for antennas separated by a specified minimum cosite distance on the ground, for antennas in a common enclosure that are separated by a known isolation factor, and for antennas on an aircraft with pre-calculated path loss.

The guardbands for the Cosite Guardband Table are based on a desired signal level equal to the threshold value of acceptable signal above receiver sensitivity. Therefore, the table represents guardbands necessary for the weakest permissible desired signal.

BACKGROUND FILE

The background file produced and printed by the TCAP lists all the nets in the order that they appear in the separation matrix, the number of equipments in each net, and the applicable frequency resource list. As explained earlier (page 36), the resource lists are required only if the user desires to generate a specific frequency assignment after the TCAP produces the channel-separation matrix.

The printed background file is arranged as follows:

$NETID_1$	NUMBER OF $EQUIPMENTS_1$	LIST $NUMBER_1$
$NETID_2$	NUMBER OF $EQUIPMENTS_2$	LIST $NUMBER_2$
$NETID_3$	NUMBER OF $EQUIPMENTS_3$	LIST $NUMBER_3$
.	.	.
.	.	.
.	.	.
$NETID_N$	NUMBER OF $EQUIPMENTS_N$	LIST $NUMBER_N$.

CHANNEL-SEPARATION MATRIX

The channel-separation matrix produced and printed by the TCAP is a net-by-net array produced from the original equipment-by-equipment array by selecting the maximum separation value between each net pair. The equipment-by-equipment array is preserved in storage and, by special techniques, can be printed out if required. The printed net-by-net separation array is arranged in the following manner, where ΔF_{ij} = required separation between nets i and j.

$$\Delta F_{1,1}, \Delta F_{1,2}, \Delta F_{1,3} \ldots \ldots \ldots \ldots \Delta F_{1,20}$$

$$\Delta F_{1,21}, \Delta F_{1,22} \ldots \ldots \Delta F_{1,80} \ldots \Delta F_{1,N}$$

$$\Delta F_{2,2} \ldots \ldots \ldots \ldots \ldots \ldots \Delta F_{2,N}$$

$$\Delta F_{3,3} \ldots \ldots \ldots \ldots \ldots \ldots \Delta F_{3,N}$$

$$\vdots$$

$$\Delta F_{N-2,N-2}, \Delta F_{N-2,N-1}, \Delta F_{N-2,N}$$

$$\Delta F_{N-1,N-1}, \Delta F_{N-1,N}$$

$$\Delta F_{N,N}$$

SECTION 6

RUN PROCEDURE AND I/O FORMATS

RUN PROCEDURE

The basic TCAP runstream is as follows:

```
@RUN. . . . . . . .
@ASG,AX IMHOF*LFICS1/U.
@ASG,OPTIONS BGFILE/U/WRITEKEY. (See Note 1)
@ASG,OPTIONS EQPFIL/U/WRITEKEY. (See Note 1)
@ASG,OPTIONS NETFIL/U/WRITEKEY. (See Note 1)
@ASG,OPTIONS PLTMSG/U/WRITEKEY. (See Note 2 & 3)
@ASG,OPTIONS PLTSRS/U/WRITEKEY. (See Note 2 & 3)
@ASG,OPTIONS PLTMTX/U/WRITEKEY. (See Note 2 & 3)
@PACK IMHOF*LFICS1/U.
@PREP IMHOF*LFICS1/U.
@MAP,IS  , IMHOF*LFICS1/U. MAIN
IN IMHOF*LFICS1/U. MAIN
LIB IMHOF*LFICS1/U.
END
@XQT IMHOF*LFICS1/U.MAIN
BACKGROUND FILE ID CARD
EQUIPMENT FILE ID CARD
NET FILE ID CARD
CONSTANTS CARD
MINIMUM SIGNAL PLOT FILE ID CARD (See Note 3)
SIGNAL-TO-SENSITIVITY PLOT FILE ID CARD (See Note 3)
CHANNEL SEPARATION MATRIX PLOT FILE ID CARD (See Note 3)
CONTROL CARD
AIRCRAFT DISTANCE/ALTITUDE CARDS (OPTIONAL)
BUILD/PRINT CARD
DEPLOYMENT CARDS (ONE FOR EACH EQUIPMENT)
TRANSMITTER PARAMETER CARDS (ONE FOR EACH TX TYPE)
RECEIVER PARAMETER CARDS (ONE FOR EACH RX TYPE)
FDR CARDS (ONE FOR EACH TX TYPE-TO-RX TYPE PAIR)
SPECIAL FDR CARDS (OPTIONAL)
COSITE PARAMETER CARDS (ONE FOR EACH TX TYPE-TO-RX TYPE PAIR)
@ ASG,T 2., T, PLOT TAPE NUMBER
@ REWIND 2.
@ ERS TPF$.
@ PACK IMHOF*FRFNEW/U.
@ MAP,IS  , IMHOF*FRFNEW/U.NEWHST/MAP,.NEWHST    See Note 3
IN IMHOF*FRFNEW/U.NEWHST
LIB IMHOF*FRFNEW/U.
LIB ECAC*CALCOMP/U.
LIB ECAC*MODLIB/U.
```

```
LIB ECAC*LIB/U
END
@XQT IMHOF*FRFNEW/U.NEWHST
CONTROL CARD FOR FIRST PLOT
D       CARD FOR FIRST PLOT
A       CARD FOR FIRST PLOT
F       CARD FOR FIRST PLOT
@REWIND 2.
@MOVE 2., 1
@XQT IMHOF*FRFNEW/U.NEWHST                  See Note 3
CONTROL CARD FOR SECOND PLOT
D       CARD FOR SECOND PLOT
A       CARD FOR SECOND PLOT
F       CARD FOR SECOND PLOT
@REWIND 2.
@MOVE 2., 2
@XQT IMHOF*FRFNEW/U.NEWHST
CONTROL CARD FOR THIRD PLOT
D       CARD FOR THIRD PLOT
A       CARD FOR THIRD PLOT
F       CARD FOR THIRD PLOT
@PMD, E
@FIN
```

Normally, the deployment cards, equipment parameter cards, FDR cards and cosite parameter cards are replaced by on-line card image files. The use of these files reduces card handling errors, especially if repetitive runs are made using common data cards. Any time a card image file is used, the data cards in the run deck are replaced by a single card of the form:

```
@ADD QUALIFIER*FILENAME.
```

NOTE 1: BGFILE, EQPFIL, and NETFIL are arbitrary names chosen to define and identify the output background file, the equipment matrix file, and the net matrix file. Any name may be used, but the corresponding assign and file ID Cards must have the same name.

NOTE 2: PLTMSG, PLTSRS and PLTMTX are arbitrary names chosen to define and identify the output plot files for the minimum signal levels, the signal-to-sensitivity ratios and the channel separation matrix. Any name may be used, but the corresponding assign and file ID cards must have the same name.

NOTE 3: These cards are required only if the histogram plots are used. They must be removed if no plot is made.

INPUT FORMATS

The format required for each data card type in the runstream is given below in proper sequential order. When the user chooses to replace cards with card image files, the files must employ the same format. Where specific card fields are required, the required columns and format are given. Some files are free-formatted where the data items are separated by a comma. In those cases, the columns are marked free and the format of the variable is given under FORMAT.

OUTPUT FILE ID CARDS

Item	Columns	Format	Description
1	1-6	A6	File Name
2	10-15	A6	Writekey
3	20	A1	Classification

The above format is applicable to the background file ID card, the equipment file ID card, and the net file ID card.

CONSTANTS CARD

Item	Columns	Format	Description
1	Free	F	Frequency (MHz) used for Cosite Low Band Calculations (see p. 6)
2	Free	F	Frequency (MHz) used for Cosite High Band Calculations
3	Free	I	MINSEP-Recovery Frequency Separation value (kHz) (see p. 38)
4	Free	F	Frequency (MHz) used in Propagation Loss Computations
5	Free	I	Terrain Type 1 through 6 (see p. 33)
6	Free	F	Channel Width (kHz)
7	Free	I	Plot Option; 1 = Plot Blank = No Plot

PLOT FILE ID CARDS

These cards use the same format as the OUTPUT FILE ID CARDS on the previous page.

CONTROL CARD

Item	Columns	Format	Description
1	1-3	A3	Aircraft in Deployment Yes or No (Blank is interpreted as No)
2	6-7	I2	Number of Aircraft Types (Blank if no A/C in deployment)
3	15-17	A3	Satellites used in Deployment Yes or No (Blank = No)
4	20-25	F6.1	Satellite ERP (dBm) (Blank if satellites not considered)
5	30-35	F6.1	Weakest ERP to Satellite (dBm) (Blank if Satellite not considered)
6	40-42	A3	Air-to-Ground desired only (No Ground-to-Ground except Interference, Yes or No, No = Blank)

AIRCRAFT DISTANCE/ALTITUDE CARDS(S)

Item	Columns	Format	Description
1	Free	F	Type 1 Aircraft Maximum Communications Range (mi)
2	Free	F	Type 1 Aircraft Maximum Communications Altitude (ft)
3	Free	F	Type 1 Aircraft Minimum Communications Altitude (ft)
4	Free	F	Type 2 Aircraft Maximum Communications Range (mi)
.	.	.	.
.	.	.	.
.	.	.	.
4N	Free	F	Type N, Aircraft Minimum Communications Altitude[a] (ft)

[a]Order of range/altitudes determines numeric type (1, 2, 3, etc.) which corresponds to aircraft type in deployment file (p. 36). N must equal the Number of Aircraft Types given on the Control Card from the previous page.

BUILD/PRINT CARD[a]

Item	Columns	Format	Description
1	1-5	A5	Enter "Build" if Background File Generation Desired (see p.)
2	11-15	A5	Enter "Print" if Printout of BG File Desired and net-by-net matrix desired

[a]The background file need only be built once for a given deployment. Successive TCAP runs using the same deployment do not need to build this on-line file but may use the one from a previous run.

DEPLOYMENT CARDS[a]

Item	Columns	Format	Description
1	1-4	I4	Transmitter Type (see p. 36)
2	5-8	I4	Receiver Type (see p. 36)
3	9-12	I4	Frequency Resource List Applicable (see p.36)
	13-15	BLANK	
4	16	A1	Equipment Type (Numeric for Aircraft "S" for Satellite Earth Station; Blank = Ground Equipment)
5	17-22	A6	Net ID
6	23-31	I9	Latitude (seconds)
7	32-40	I9	Longitude (seconds)
8	41-46	A6	Unit ID
9	47-49	I3	Antenna Enclosure ID[b] (see p. 36)

[a]One card for each equipment in the deployment; the last card must be followed by a @EOF card.

[b]Blank if equipment antenna is not in a housing with other antennas.

TRANSMITTER PARAMETER CARDS[a]

Item	Columns	Format	Description
1	Free	I	Transmitter Type
2	Free	F	Transmitter Power (dBm)
3	Free	F	Transmitter Antenna Gain (dBi)
4	Free	F	Effective Cosite Antenna Gain (dBi)[b]

RECEIVER PARAMETER CARDS[a]

Item	Columns	Format	Description
1	Free	I	Receiver Type
2	Free	F	Receiver Antenna Gain (dBi)
3	Free	F	Receiver Sensitivity (dBm)
4	Free	F	Effective Cosite Antenna Gain (dBi)[b]
5	Free	F	Minimum Signal-To-Sensitivity Ratio (dB)

[a]One card for each transmitter and receiver type in deployment; the last card must be followed by a @EOF card for both files.

[b]Supplied by ECAC as part of the Cosite Coupling Model (Reference 7).

FREQUENCY-DEPENDENT-REJECTION DATA POINTS CARD[a]

Item	Columns	Format	Description
1	Free	I	Transmitter Type
2	Free	I	Receiver Type
3	Free	F	ΔF_1
4	Free	F	FDR_1 (dB)
5	Free	F	ΔF_2
6	Free	F	FDR_2
7	Free	F	ΔF_3
8	Free	F	FDR_3
.	.	.	.
.	.	.	.
.	.	.	.
21	Free	F	ΔF_{10}
22	Free	F	FDR_{10}
23	Free	F	Threshold S/I for TX/RX (dB)

[a]One card for each Transmitter-Type/Receiver-Type Pair. The last card must be followed by a @EOF card. Ten ΔF-FDR data pairs must be supplied for each equipment pair.

SPECIAL SATELLITE FDR DATA POINTS CARD

SAME AS PRECEDING FDR DATA CARD EXCEPT RECEIVER TYPE ALWAYS IS ZERO (NOT BLANK). THE LAST CARD IS FOLLOWED BY A @EOF CARD.

COSITE PARAMETER CARDS[a]

Item	Columns	Format	Description
1	1-5	I5	Transmitter Type
2	6-10	I5	Receiver Type
3	11-15	I5	Polarizations (1 = Cross polarized, 0 = Same polarization)
4	16-20	F5.0	Cosite Distance (ft) (For use in cosite coupling computations)
5	21-25	F5.0	TX Antenna Height (ft)
6	26-30	F5.0	RX Antenna Height (ft)
7	31-35	F5.0	Isolation Factor for TX/RX antenna in same housing (dB)[b]
8	36-40	F5.0	Aircraft Type Number
9	41-45	F5.0	Aircraft Path Loss (dB)

[a]One card for each Transmitter-Type/Receiver-Type Pair .

[b]Blank if Transmitter-Type/Receiver-Type is never found in a common enclosure. Last card must be followed by a @EOF card.

OUTPUT FORMAT

The outputs from the TCAP fall into two categories:

1. Input verification printouts
2. Program results.

Input Verification Printouts

All inputs are printed out for verification purposes in the same sequence as shown under INPUT FORMATS, with sufficient information to identify each variable.

PROGRAM RESULTS

The program results obtained from the procedures described herein are:

1. Cosite guardband table
2. Performance failure messages
3. Background file
4. Channel separation matrix
5. Histogram plots.

Sample outputs are given in Figures 14, 15, 16, 17. Formats of the background file and channel separation matrix were described in detail in the preceding section.

COSITE GUARDBAND TABLE

TX TYPE	RX TYPE	TX ANT HT (FT)	RX ANT HT (FT)	GND SEPAR DIST (FT)	REL POL	ANT ISOL (DB)	A/C COUPL (DB)	LO BAND GB (MHZ)	HI BAND GB (MHZ)	AVG GB (MHZ)	SHELTER GB (MHZ)	A/C GB (MHZ)
10	10	20.0	20.0	8.0	0	30.0		7.75	6.90	7.33	6.25	
10	11	20.0	20.0	8.0	0	30.0		1.85	1.70	1.78	1.55	
10	12	20.0	20.0	200.0	0			8.20	6.10	7.15		
10	13	20.0	10.0	200.0	0			9.05	6.70	7.88		
10	15	20.0	20.0	200.0	0			.65	.60	.62		
11	10	20.0	20.0	200.0	0			1.45	1.25	1.35		
11	11	20.0	20.0	200.0	0			5.10	4.40	4.75		
11	12	20.0	20.0	200.0	0			9.30	6.95	8.13		
11	13	20.0	10.0	200.0	0			10.20	7.60	8.90		
11	15	20.0	20.0	200.0	0			.65	.60	.62		
12	10	20.0	20.0	8.0	0	30.0		10.00	8.90	9.45	8.10	
12	11	20.0	20.0	8.0	0	30.0		2.20	2.05	2.13	1.90	
12	12	20.0	20.0	200.0	0			15.80	11.80	13.80		
12	13	20.0	10.0	200.0	0			17.40	13.05	15.23		
12	15	20.0	20.0	200.0	0			.80	.70	.75		
13	10	10.0	20.0	200.0	0			.60	.55	.57		
13	11	10.0	20.0	200.0	0			1.95	1.65	1.80		
13	12	10.0	20.0	200.0	0			2.15	1.80	1.98		
13	13	10.0	10.0	200.0	0			2.35	1.95	2.15		
13	15	10.0	20.0	200.0	0			.45	.40	.42		
14	10	20.0	20.0	200.0	0			.85	.75	.80		
14	11	20.0	20.0	200.0	0			2.90	2.50	2.70		
14	12	20.0	20.0	200.0	0			3.65	3.00	3.33		
14	13	20.0	10.0	200.0	0			3.90	3.20	3.55		
14	15	20.0	20.0	200.0	0			.50	.45	.47		
15	14	5.0	5.0	50.0	0		50.0	.50	.45	.47		.57
16	10	20.0	20.0	200.0	0			1.15	1.00	1.08		
16	11	20.0	20.0	200.0	0			.70	.65	.67		
16	12	20.0	20.0	200.0	0			.70	.65	.67		
16	13	20.0	10.0	200.0	0			.75	.70	.72		

GB - Guardband using cosite coupling model
Shelter GB - Guardband using antenna isolation factor
A/C GB - Aircraft cosite guardband

Figure 14. Cosite guardband table.

```
THE S/RS BETWEEN THE TRANSMITTER WITH UNIT ID WHEZDY OF NET WR044
AND THE RECEIVER WITH UNIT ID WHAZZZ OF NET WR044 IS LESS THAN
THE REQUIRED MINIMUM S/N OF 5.0008.
                                   TX TYPE   =  14
                                   RX TYPE   =  14
                                   DISTANCE  =  100  MILES
                                   PROP LOSS =  -126  DB
                                   S/RS      =  3.57 DB

     I  =  73
     I  =  74
     I  =  75
     I  =  76
     I  =  77
     I  =  78
     I  =  79
     I  =  80

THE FAR-SITE FREQUENCY SEPARATION BETWEEN NETS WR050, WR052
TWO OF WHOSE UNIT IDS ARE WHDZZZ, WHDZZZ IS GREATER THAN TWENTY MHZ.
                                   DES. TX TYPE   =  15
                                   UND. TX TYPE   =  11
                                   DES. RX TYPE   =  12
                                   DISTANCE       =  .192-01 MILES
                                   PROP. LOSS     =  -39.5 DB
                                   S/I            =  -85.9 DB
                                   FREQ. SEP.     =  22.6 MHZ
                                   DES. SIG.      =  -71.4 DBM
                                   UND. SIG.      =  14.5 DBM
```

Figure 15. Sample failure messages.

(Separations given in 10 kHz channels. e.g., 524 = 5.24 MHz)

0	73	25	25	23	25	23	25	23	22	33	25	46	196	161
0	25	25	23	25	23	25	23	22	33	25	46	197	161	
0	73	73	73	73	73	73	38	34	73	29	145	312		
0	73	73	73	73	73	73	31	73	28	144	312			
0	73	73	73	73	73	29	73	27	140	312				
0	73	73	73	41	31	73	28	144	312					
0	73	73	73	29	73	27	140	312						
0	73	40	32	73	28	145	312							
0	73	28	41	26	139	220								
0	27	38	26	138	211									
0	34	34	162	195										
0	28	145	312											
0	288	145												
0	0													
0														

THE FOLLOWING IS A LIST OF THE NETS IN THIS DEPLOYMENT. THE NUMBER OF EQUIPMENTS IN EACH NET AND THE FREQUENCY LIST NUMBER TO BE ASSOCIATED WITH THE NET IN THE EVENT A FREQUENCY ASSIGNMENT IS TO BE MADE SUBSEQUENT TO THIS RUN.

IMMEDIATELY FOLLOWING THE NET LIST IS THE MATRIX OF MINIMUM FREQUENCY SEPARATIONS REQUIRED BETWEEN NETS. THE SEPARATIONS ARE GIVEN AS THE NUMBER OF 10. KHZ CHANNELS REQUIRED. THE ROWS OF THE MATRIX ARE SEPARATED BY BLANK LINES. ONLY THE UPPER RIGHT HALF OF THE MATRIX IS GIVEN. THE FIRST ROW IS THE FIRST NET IN THE NET LIST VERSUS ITSELF AND ALL OTHER NETS IN THE SEQUENTIAL ORDER THAT THEY ARE GIVEN IN THE NET LIST. THE SECOND ROW IS THE SECOND NET FROM THE LIST VERSUS ITSELF AND ALL OTHER NETS BELOW IT IN THE LIST.

NET LIST

NET ID	# OF EQUIP.	FREQ. LIST #
WR022	2	6
WR027	2	6
WR033	2	6
WR023	2	6
WR029	2	6
WR024	2	6
WR030	2	6
WR025	2	6
WR031	2	6
WR032	2	6
WR026	2	6
WR028	2	6
WR018	2	6
SAT1	4	7
SAT2	2	5

Figure 16. Net-by-net separation matrix and corresponding background file printouts.

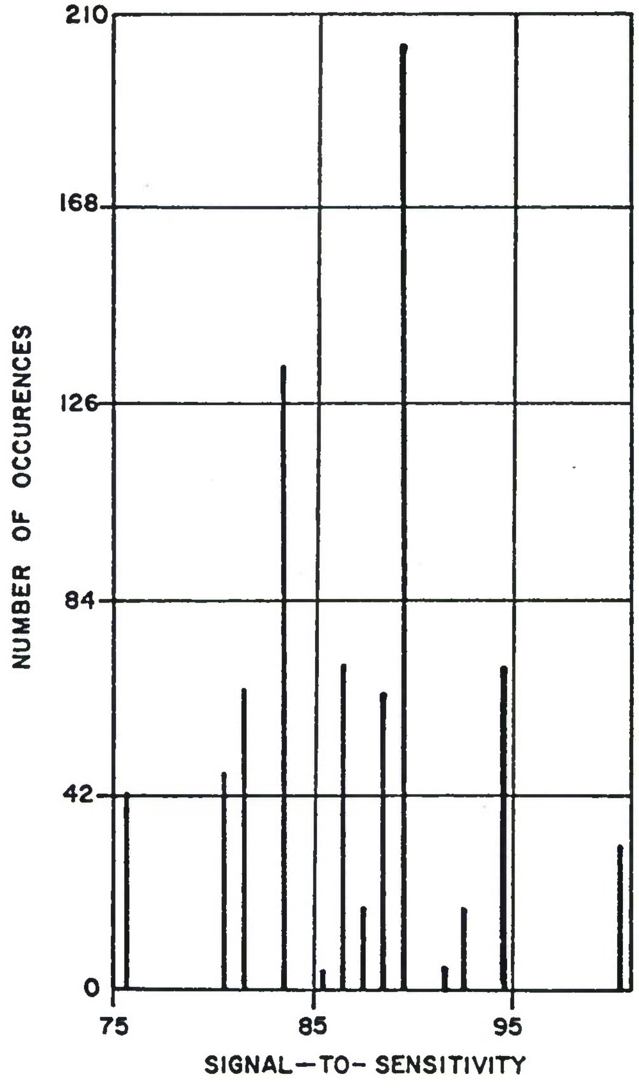

Figure 17. UHF signal-to-sensitivity histogram plot.

SECTION 7

DATA PREPARATION SUBPROGRAMS

GENERAL

Two programs have been developed to aid in the preparation of some of the input data required by TCAP. These programs need be used only if the data has not been previously developed. The programs are concerned with the generation of the FDR data, and the aircraft antenna coupling loss for regular shaped aircraft. These programs are described here.

FDR FILE GENERATION ROUTINE (FDRCRD)

The frequency-dependent rejection card image file generation program (FDRCRD) was developed to eliminate the manual steps between developing FDR data and selection of the proper ten data points required for TCAP. The FDRCRD routine was extracted from the Aircraft Channel Analysis Program.[11] Originally, it was necessary to use the OFRCAL[12] program to generate the FDR data, then plot the data to determine the breakpoints, extract the proper data points, and finally punch the cards for input to TCAP. FDRCRD uses the data file generated by OFRCAL intended for the plot program and automatically selects exactly ten FDR data points by detecting slope changes. These data points, as well as the minimum S/I, are then put in a card image file for use by TCAP.

---

[11] Mullen, R., et al., *AWACS Avionics Analysis,* ECAC-PR-75-068, APPENDIX A, ECAC, Annapolis, MD, October 1975.

[12] Harris, R., *OFR and FD Analysis With Program OFRCAL,* ECAC-TN-71-025, ECAC, Annapolis, MD, September 1971.

The runstream for FDRCRD is as follows:

```
@RUN . . . . . . . . .
@ASG,CP FDRFIL/U.[a](output file for OFRCAL)
  OFRCAL RUN DECK[b](ECAC-TN-71-25)
@ERS
@ASG,CP CRDFIL/U[a](card image file for FDR)
@USE 1., FDRCRD/U.
@USE I., IMHOF*FDRCRD/U.
@ASG,AX I.
@PREP I.
@MAP,IS, I.
@XQT I.
FILE CONTROL CARD
CONSTANTS CARD
DATA CARDS
SLOPE CARD
@FIN
```

The format of the cards required by FDRCRD are given below in proper sequential order.

FILE CONTROL CARD

Item	Column	Format	Description
1	1-6	A6	Name of the file containing the FDR data from OFRCAL
2	10-15	A6	Write key for the file
3	20	A1	Security classification of the file

[a]The file names used here are arbitrary and may be any name chosen by the user.

[b]Select OFR, log right side only, and ISEQ=2 in OFRCAL.

CONSTANT CARD

Item	Column	Format	Description
1	Free	I3	Total number of transmitters
2	Free	I3	Total number of receivers
3	Free	I3	Total number of transmitters-receiver combinations

DATA CARDS[a]

Item	Column	Format	Description
1	Free	I3	Transmitter type number
2	Free	I3	Receiver type number
3	Free	F8.3	Minimum S/I for this transmitter-receiver pair

[a]One card required for each transmitter-receiver pair.

SLOPE CARD

Item	Column	Format	Description
1	Free	F4.1	Value used to compare difference in slope. A value of 20 is suggested.

AIRCRAFT PATH LOSS ROUTINE (AIRCUP)

AIRCUP will provide the path loss between antennas on any aircraft which can be approximated by a cylindrical or conical section. These path loss values are required by the TCAP for the aircraft cosite calculations. AIRCUP is an extraction from the AVPAK system (Reference 8).

The runstream for AIRCUP is as follows:

```
@RUN
@ASG,AX IMHOF*AIRCUP/U.
@PACK IMHOF*AIRCUP/U.
@PREP IMHOF*AIRCUP/U.
@MAP,IS  , IMHOF*AIRCUP/U.AVCALC
IN IMHOF*AIRCUP/U.AVCALC
LIB IMHOF*AIRCUP/U.
END
@XQT IMHOF*AIRCUP/U.AVCALC
NUMBER OF AIRCRAFT CARD
AIRFRAME DATA CARD
NOMENCLATURE CARD                          one set
ANTENNA DATA CARDS           (99 MAX)      for each
COUPLET DATA CARDS           (99 MAX)      aircraft
@PMD, E
@FIN
```

The format for the data cards is as given below. The cards are listed in the proper sequential order for the program.

NUMBER OF AIRCRAFT CARD

Columns	Format	Description
1-5	I5	The number of aircraft to be considered during this run

AIRFRAME DATA CARD

Columns	Format	Description
2-5 7-10 11-14	F4.0 F4.0 F4.0	Maximum radius of fuselage (ft) Bulkhead distance (OPTIONAL) (ft) Bulkhead radius (OPTIONAL) (ft)

NOMENCLATURE CARD

Columns	Format	Description
1-6	A6	Nomenclature of the aircraft

ANTENNA DATA CARDS

Columns	Format	Description
1-2	I2	Antenna number
4-7	F4.0	Antenna height (ft)
9-12	F4.0	Antenna angle (degrees)
14-17	F4.0	Fuselage station number (ft)

Antenna height is referenced to aircraft centerline.

Antenna angle is measured looking into the front of the aircraft in a clockwise direction from the top.

Fuselage station is measured from a reference point at or near the nose of the aircraft.

The last antenna card should have 00 in columns 1 and 2.

COUPLET DATA CARD

Columns	Format	Description
1-2	I2	Number of the first antenna of the couplet
4-5	I2	Number of the second antenna of the couplet
7-11	F5.0	Frequency (MHz)

The last couplet card should have 00 in columns 1 and 2.

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